Note

WATER CONSUMPTION OF THE ESTEVIA (*Stevia rebaudiana* (Bert.) Bertoni) CROP ESTIMATED THROUGH MICROLYSIMETER

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ABSTRACT: The knowledge of water requirement of crops in the different growing phases elicits higher crop yield and rational use of water resource. The aim of this work was to estimate the water consumption of stevia using two constant watertable microlysimeters. The research was conducted in San Piero a Grado, Pisa, Italy. The data were collected daily from June, 1st, to October, 22th, 2000. Reference evapotranspiration was determined by the Penman-Monteith-FAO method, in the same period. Microlysimeters watertables level were maintained at the 35 cm depth. Crop evapotranspiration for the total cicle (80 days) was 464 mm. For the most water consuming phase, crop average evapotranspiration was 5.44 mm day^{-1}. The crop coefficient values were 1.45 for the first 25 days, 1.14 for the next period (26 to 50 days), and 1.16 for the latest period (51 to 80 days). The stevia leaf yield of the microlysimeters was 4.369 kg ha^{-1} and their steviosideo content 6.49%.
Key words: lysimeter, water requirement, evapotranspiration

CONSUMO DE ÁGUA DA CULTURA DE ESTÉVIA (*Stevia rebaudiana* (Bert.) Bertoni) ESTIMADO POR MICROLISÍMETRO

RESUMO: O estudo das necessidades hídricas das plantas cultivadas nas diferentes fases de desenvolvimento vegetativo permite a obtenção de melhor rendimento e o uso racional dos recursos hídricos. Este trabalho teve como objetivo estimar o consumo hídrico da cultura da estévia utilizando dois microlisímetros com nível d'água constante. A pesquisa foi realizada em San Piero a Grado, Pisa, Itália. Os dados de evapotranspiração foram coletados diariamente durante o período de primeiro de junho a 22 de outubro de 2000. A evapotranspiração de referência foi determinada pelo método Penman-Monteith-FAO durante o mesmo período. O nível d'água dos dois microlisímetros foi mantido a 35 cm da superfície do solo. A evapotranspiração da cultura durante todo ciclo (80 dias) foi de 464 mm. Os valores médios de evapotranspiração para a fase de maior consumo, ou seja, fase final, foram de 5,44 mm dia^{-1}. Os valores de coeficiente de cultura foram de 1,45 para a fase inicial, 1,14 para a intermediária e 1,16 para a fase final do desenvolvimento da cultura. O rendimento de folhas da cultura foi de 4,369 kg ha^{-1} e o teor de esteviosídeo de 6.49%.
Palavras-chave: lisímetro, consumo hídrico, evapotranspiração

INTRODUCTION

Stevia has been cultivated in several countries because of the sweetness of the leaf extract, a sweetener power 300 times greater than sugar-cane. Stevia sweetener is largely consumed by diabetics or by people who need special diets. Stevia is cultivated in small areas as a good option of high lucrativity per unit area. After 30 years of economic cultivation, stevias' yield is still low mainly because no information is available on water consumption on different growing phases. This information can be determinated through lysimeters, equipment that permits measuring the real crop evapotranspiration in the field. Lysimeters are recipients with high soil volume, with or without plant installed in similar conditions of crop area (Aboukhaled et al., 1982). Looking for easier alternatives to estimate water consumption and crop coefficient, researches developed and use constant watertable microlysimeters. In this sense, the National Irrigation Laboratory the University of Pisa tested for 10 years a watertable microlysimeter of low cost and very practical. Installed in the field, it permits that data on daily evapotranspiration and the decision for the irrigation intensity and moment are made easily (Bertolacci & Megale, 1999; Valadão, 1995; Cury & Villa Nova, 1987).

The aim of this work was to estimate the water consumption of stevia using two constant watertable microlysimeters. In addition, crop coefficient for three phases was determined by reference evapotranspiration, estimated with Penman-Monteith-FAO method (Allen et al., 1998), and real evapotranspiration measured with microlysimeters.

MATERIAL AND METHODS

The research was conducted in San Piero a Grado, Pisa, Toscana Province, center-west of Italy (43ºN, 11ºE; altitude 5m). The region climate is Mediterranean, with rainy fall and spring. In the summer and winter, rain is little or non-existent. Summer temperature ranges on 20ºC to 30ºC, with few days over 35ºC. The soil of the experimental area has 510 g kg^{-1} of sand, 390 g kg^{-1} of silt and 100 g kg^{-1} of clay.

The water consumption (real evapotranspiration = ETc) was determined by two watertable microlysimeters and the reference evapotranspiration (ETo) was estimated by the Penman-Monteith-FAO method (Allen et al., 1998) using the equation:

$$ETo = \frac{0.408\,\Delta(Rn - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 U_2)} \quad (1)$$

where: ETo – reference evapotranspiration (mm day^{-1}); Rn – net radiation at the crop surface (MJ m^{-2} day^{-1}); G – soil heat flux density (MJ m^{-2} day^{-1}); T – mean daily air temperature at 2 m height (ºC); U_2 – wind speed at 2 m heigt (m s^{-1}); e_s – saturation vapor pressure (kPa); e_a – actual vapor pressure (kPa); (e_s - e_a) – saturation vapor pressure deficit (kPa); Δ - slope vapor pressure curve (kPa ºC^{-1}); γ - psychometric constant (kPa ºC^{-1}).

The net radiation (Rn) is the difference between incoming net shortwave (Rns) and the net outgoing longwave radiation (Rnl), both calculated for local area. The daily data required are: maximum and minimum temperature, wind speed, incoming solar radiation and (maximum and minimum) relative air humidity.

The coefficient crop (Kc) was calculed as ratio of the ETc to the ETo. Equipments were installed in two central plots inside 400 m^2 area. Next to the microlysimeter there were five stevia plots (five meters with crop). The microlysimeters were 0.50 m in depth, 1.4 m in length and 1.2 long (1.68 m^2 area). Within the microlysimeters, there were ten plants with stand of 0.30 m x 0.50 m (66,666 plants per hectare). The water movement was by capillary ascension (Figure 1).

A layer with 0.10 m of small stones and a plastic fabric to avoid blockage, were installed in the microlysimeter. The watertable was maintained at 0.35 m depth by buoy. The water was always in contact with soil (0.05 m). Water consumption was replaced and registered by mechanic accountant (pulse accountant); each pulse contained 60 cm^3 of water.

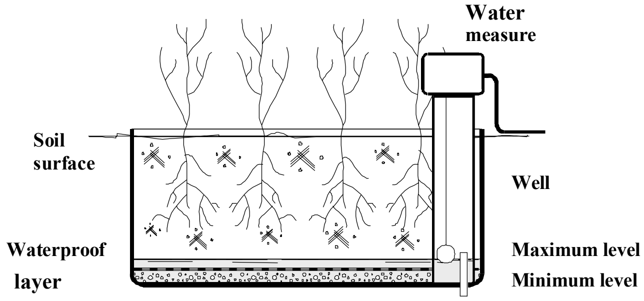

Figure 1 - Design of capillary ascension microlysimeter. Adapted from: Irrigation National Laboratory, University of Pisa, Italy.

The stevia crop (*Stevia rebaudiana* Bert.) was installed in the field in 1999, exclusively out of native species. Generally the best leaf yielding level occurs from the second to the fifth year of cultivation (Carneiro et al., 1997); data were obtained during 2000. Every morning, 08h00, water consumption data were recorded by accountant pulse of the last 24 hours and multiplied by the water volume in one pulse. After that, a ratio between the consumed water volume and the microlysimeter area (1.68 m^2)was estimated to obtain the daily evapotranspiration (mm day^{-1}). Stevia was harvested made at the 80th day after sprout, when 10% of plants were in flower, and concentration of steviosideo and leaf yielding were the highest.

RESULTS AND DISCUSSION

Water consumption

In the first days of growth, water consumption was high (Table 1), in contradiction to the initial expectation of small evapotranspiration. Generally in the initial phase, evaporation and minimum transpiration occur because of the small leaf area of plants. This high consumption occurred because of the fill pore, which was empty (in the first days), and mainly because of the high humidity of the soil, which permitted the water evaporation on microlysimeters. In this condition, evaporation is similar or higher than evaporimeters-type tank. It is easy to understand because of the watertable being only at 0.35 m from the surface and the gray color of the soil. In this phase, days are 15.3 hours long, with high solar radiation incoming (June).

Sousa (1992) found high initial ETc for cotton in this type of microlysimer and similar situation (watertable near the surface). The evapotranspiration was three times bigger when the watertable was at 0.25 m, as compared to the watertable at 0.75 m. The evapotranspiration values went from 1.5 to 4.5 mm day^{-1}. The author explained that this difference occurs only in the first growing phase. After that, soil was completely covered. Evapotranspiration was similar in all treatments.

The high evaporation was enhanced by soil silt, 39%, plus 10% clay, what makes the capillary ascension easier. This problem could be eliminated by using a small layer of sand atop the soil (2-3 cm), but it could impair the minimum air for the plants. The solution could be to increase watertable depth.

In rain events, water consumption varied to a bigger extent (Figure 2). This occurred because the water storage in the soil kept the wartertable high. The crop was in evapotranspiration, but using the water storage, with no pulse registration because of the pore saturation.

Figure 3 brings data of five days average are showed, calculated by daily data (out of Figure 2). Data were more uniform, because rain effects had been reduced. Becker (1990) and Sousa (1992) explain that recording water incoming in the lysimeter in the rain moments is very important to avoid losing data. That is why Barbieri (1981) recommends that for better uniformity and representativity of Etc, wartertable lysimeters data to be analyzed every five or more days.

Table 1 - Stevia's water consumption in the microlysimeters in 2000.

Period	Microlysimeter 1	Microlysimeter 2	Average
	------------ mm day^{-1} ------------		
06/06-10	7.85	7.89	7.87
06/11-15	7.79	7.95	7.87
06/16-20	7.56	7.03	7.30
06/21-25	6.57	5.72	6.15
06/26-30	5.89	4.82	5.35
07/01-05	5.79	4.99	5.39
07/06-10	5.83	5.22	5.53
07/11-15	5.19	4.93	5.06
07/16-20	4.72	4.51	4.62
07/21-25	5.66	5.90	5.78
07/26-30	4.59	4.52	4.55
08/31-04	5.94	4.92	5.43
08/05-09	6.77	6.44	6.61
08/10-14	4.35	4.37	4.36
08/15-19	5.04	5.19	5.11
08/20-22	5.46	6.41	5.94
Total (mm)	475.06	454.05	464.55
Average	5.94	5.68	5.81

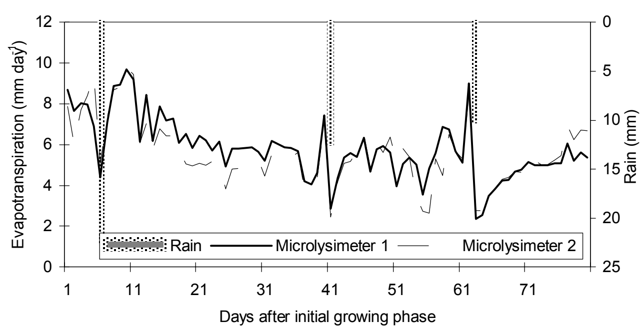

Figure 2 - Daily variation of water consumption in the cultivation period on microlysimeters.

The evapotranspiration was higher from 0 to 25 days, than from 25 to 50 days. However, a small increase from 51 to 80 days was observed. The two microlysimeters had similar measure in the total period (Figure 3), where the total consumption was 475 mm for microlysimeter 1 and 454 for microlysimeter 2, with an average of 464.5 mm (Table 1).

Reference evapotranspiration and crop coefficient of stevia

The results of ETc measured by microlysimeter are overestimate in the initial phase, where they are higher than ETo's. In this phase, for most of the crops, the ETo is higher tha ETc because of the initial growing phase of crops with small leaf area. As already commented, it is related to evaporation problems. Fontes (1996) found similar problem studying water consumption of broccoli. The overestimate of ETc was 20% when the watertable changed from 0.50 m to 0.40 m depth in the initial growing phase. Valadão (1995) found the same results for beans: ETc was 55% higher when the watertable changed from 0.75 m to 0.50 m depth. After 25 days of cultivation, ETc data presented better correlation with ETo data (Figures 4 and 5).

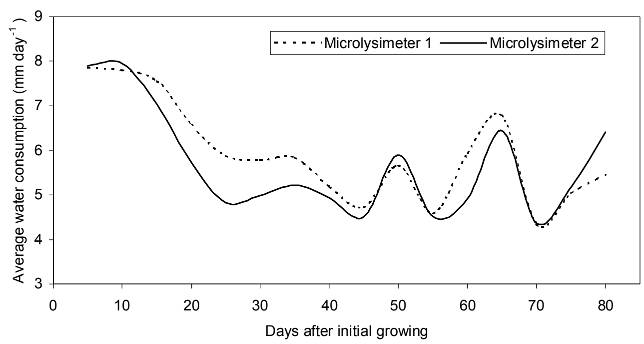

Figure 3 - Variation of water consumption in the growing period on microlysimeters (five days average data).

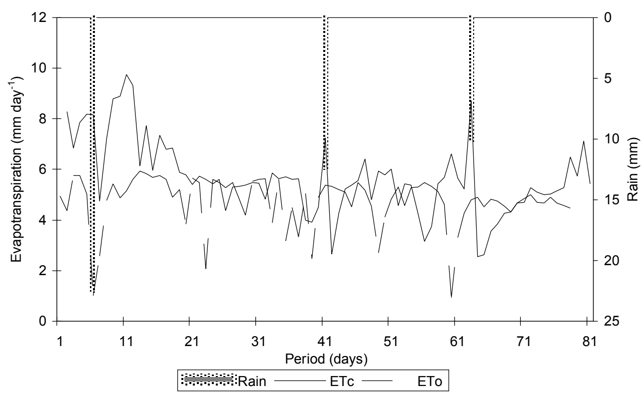

Figure 4 - Water consumption measured by microlysimeters and ETo estimate by Penman-Monteith Method for 80 days of cultivation.

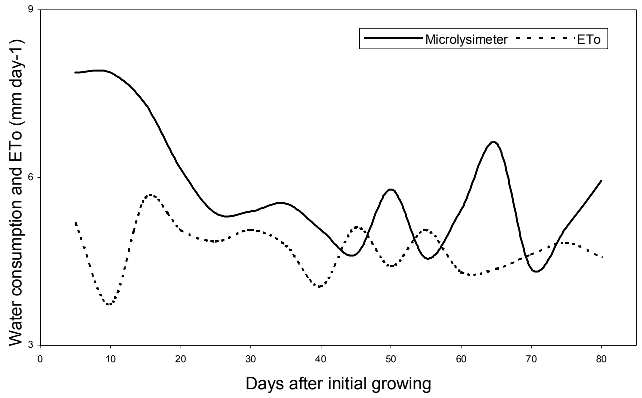

Figure 5 - Water consumption and ETo average for 5 days periods.

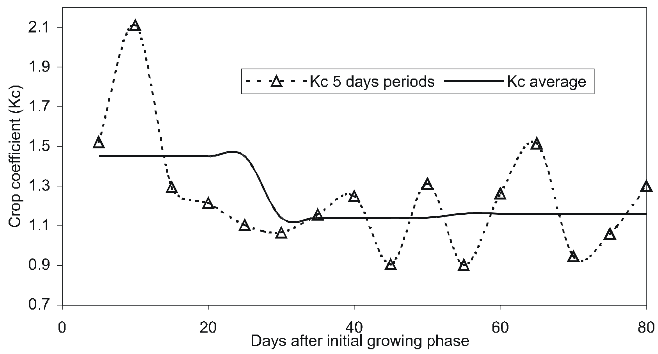

Figure 6 - Crop coefficient variation (Kc) of stevia in cycle.

Another reason for the high initial difference is the tendency of Penman-Monteith Method of presenting an underestimating ETo in a dry climate region or in a dry season. Sentelhas (1998) found an underestimative of ETo of 10% in Piracicaba – SP in a dry season. Also, Smith et al. (1996), using this method to determine ETo in 11 regions, observed underestimative of evapotranspiration data.

This research was carried out in the dry season, and only 3 rainy days occurred in the cycle (Figure 4). The ETc data were high in the initial phase of crop because of the proximity of the watertable to the soil surface, where, according to Tanner & Jury (1976), the evaporation is limited to hydraulic characteristic of soil and humidity percentage. In this case both conditions were favorable, inside the microlysimeters. The soil tension was 20 kPa in the first 10 cm off the surface, and high silt concentration (39%) increased capillary ascension. Soares (1999) found a three times higher Kc value when the soil was irrigated every four days in relation to seven days between each irrigation.

The crop coefficient value (Kc) was 1.45 from 0 to 25 days, 1.14 from 26 to 50 days, and 1.16 from 51 to 80 days (Figure 6). In the second and third periods, values are coherent with growing rate. Similar results of Kc were observed by Santos et al. (1996) for *Medicago sativum*, in the intermediary and final growing phases using the Penman-Monteith Method and scales lysimeters for ETo and ETc, respectively.

Stevia and *M. sativum* have similar leaf area indices and cycle. For *M. sativum*, the authors observed stable Kc after the first 30 days. In this research, Kc also stabilized between 1.14 and 1.16 after 25 days. The localization of the experimental area and the season allowed fast growth, resulting from high incoming radiation and liquid photosynthesis. Doorenbos & Pruitt (1977) found maximum Kc = 1.15 for Medicago, herbs and grass in the best growing phase for dry climate region; values are similar to results of this research which however, are superior to results reported by Gonzalez (2000), where the crop coefficient for stevia grown in Paraguay were 0.25; 0.56 and 0.85 (Figure 6). The different values can be justified for the yield of 4.369 kg ha^{-1} in this research, and 2.000 kg ha^{-1} observed by Gonzalez (2000), with the same equipment. The high leaf area permited more ETc and consequently more Kc. Another factor can be the seacoast area of Pisa.

The leaf area index (LAI) of stevia in the final phase was 4.83, a high value in comparison to other crops. This is understandable because, in 80 days, the stevia yield presented 4,369 kg ha^{-1} of dry leaf. The high LAI and yield are justified by long days (15.9 h), solar radiation and location of the experiment area (43ºN), close to the maximum incoming radiation for this season.

The steviosideo contend in the leaf was 6.49%, similar to values reported by Sakaguchi & Kan (1982), who described values between 5 and 15% of steviosideo for stevia crop. As the watertable microlysimeters overestimated Kc values in the initial phase, resulting from the fact that the watertable was close to the soil surface, it would be important to test the ideal depth of watertable for microlysimeters in subsequent works.

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